Post-doctoral position - Recrutement en post-doctorat 2021-2023 :

Structure-preserving discretization of boundary controlled and observed Maxwell's equations as a port-Hamiltonian system

Context

ISAE (Institut Supérieur de l'Aéronautique et de l'Espace) offers a two year post-doctoral position in Applied Mathematics in 2021-2023.

Fields: Port-Hamiltonian Systems (pHs), distributed-parameter systems (DPS), structure-preserving discretization, Finite Element Method (FEM), Python implementation.

Location: ISAE [1], Campus SUPAERO (Toulouse, France)
Duration: 24 months, starting March, 2021

The research will take place within the Department of Complex Systems Engineering (DISC) and will benefit from the stimulating environment of ISAE. This is a research-only appointment (no teaching).
The position is funded by the Agence de l'Innovation de Défense of the Ministère des Armées, by the AID Projet École: Fast and Accurate MAxwell Solver, FAMAS, which also involves the DTIS-COVNI team from the ONERA Toulouse.
The net salary will be 2 259.69 Euros per month (before deduction of income tax), health insurance and social coverage included. Speaking French is not compulsory.

Application: please send us by email:

- a curriculum vitæ,
- a list of your publications.

Recommendation letters should be sent to the contact persons mentioned below, by email.

Application deadline: **January 31st, 2021**
Contacts:
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[1] see https://www.isae-supaero.fr

Research activities

The modelling of physical systems based on the representation of intrinsic energy exchanges between different energetic domains allows a modular description of their (even complex) dynamic behaviour. In this context, the port-Hamiltonian framework represents a powerful modelling and control tool, see *e.g.* [13, 6, 11].

The objective of structure-preserving discretization methods for infinite-dimensional pHs is to construct a finite-dimensional pHs approximating the power balance of the Partial Differential Equations under study. Different methods have been suggested to this aim, see *e.g.* [8, 12, 1] and references therein.

The Partitioned Finite Element Method (PFEM) is very promising and has already been applied to electromagnetic phenomena [9]. However, several drawbacks have been identified, and must be tackled properly. Furthermore, this approach leads to large-scale finite-dimensional pHs, which prove inappropriate for control purposes, therefore structure-preserving model reduction is required [4, 7].

Methodology

The program follows as:

1. A first task will consider the questions raised in [9] about the appropriate finite element families to use, especially to take the divergence-free condition of the electric and magnetic inductions into account;
2. Second, the structure-preserving model reduction methods [5, 10] developed by the DTIS-COVNI team from ONERA Toulouse will be adapted for the finite-dimensional pHs obtained in the first step;
3. As an output of the post-doc, these strategies for electromagnetic phenomena will have to be implemented, tested, exemplified and documented in the ongoing SCRIMP collaborative project [2, 3] developped at ISAE. More precisely, a "Maxwell" class and a module for model reduction that is able to tackle Differential-Algebraic Equations (DAEs) will be fully developed.

Applications

The proposed applications are those described in the AID Projet École FAMAS. For example, it is intended to consider:

1. Various coupling between electromagnetism with heat, vibration, charged particle;
2. Meta-material for a new generation of antennas.

References

[1] A. Brugnoli, *A port-Hamiltonian formulation of flexible structures. Modelling and structure-preserving finite element discretization*, PhD thesis, Université de Toulouse, ISAE-SUPAERO, France, 2020.

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[3] A. Brugnoli, G. Haine, A. Serhani, and X. Vasseur, *Supplementary material for "Numerical approximation of port-Hamiltonian systems for hyperbolic or parabolic PDEs with boundary control"*. https://doi.org/10.5281/zenodo.3938600, 2020. Dataset on Zenodo.

[4] S. Chaturantabut, C. Beattie, and S. Gugercin, *Structure-preserving model reduction for nonlinear port-Hamiltonian systems*, SIAM Journal on Scientific Computing, 38 (2016), pp. B837–B865.

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[6] V. Duindam, A. Macchelli, S. Stramigioli, and H. Bruyninckx, *Modeling and Control of Complex Physical Systems: The Port-Hamiltonian Approach*, Springer-Verlag, Berlin Heidelberg, 2009.

[7] H. Egger, T. Kugler, B. Liljegren-Sailer, N. Marheineke, and V. Mehrmann, *On structure-preserving model reduction for damped wave propagation in transport networks*, SIAM Journal on Scientific Computing, 40 (2018), pp. A331–A365.

[8] P. Kotyczka, *Numerical Methods for Distributed Parameter Port-Hamiltonian Systems*, TUM.University Press, Munich, 2019. Habilitation.

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[11] R. Rashad, F. Califano, A. van der Schaft, and S. Stramigioli, *Twenty years of distributed port-Hamiltonian systems: a literature review*, IMA Journal of Mathematical Control and Information, (2020).

[12] A. Serhani, *Systèmes couplés d'EDPs, vus comme des systèmes Hamiltoniens à ports avec dissipation : Analyse théorique et simulation numérique*, PhD thesis, Université de Toulouse, ISAE-SUPAERO, France, 2020.

[13] A. van der Schaft and D. Jeltsema, *Port-Hamiltonian Systems Theory: An Introductory Overview*, Foundations and Trends® in Systems and Control, 1 (2014), pp. 173–378.